FOOD HABITS OF THE BALD EAGLE ON SANTA CATALINA ISLAND,

NOVEMBER 1991 - DECEMBER 1992

A report submitted to the
Damage Assessment Office
U.S. Fish and Wildlife Service
Sacramento Field Office
Sacramento, California

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March 1997

INTRODUCTION

The bald eagle (*Haliaeetus leucocephalus*) is listed as threatened in the 48 contiguous states (U.S. Fish & Wildl. Serv. 1995). The decline of bald eagles in many areas has been correlated with high levels of organochlorine compounds, and specifically with metabolites of DDT (dichloro diphenyl trichloroethane) (Stickel et al. 1966, Krantz et al. 1970, Wiemeyer 1972, 1984, Grier 1974). DDT is an organochlorine contaminant which is metabolized in the environment and in animals to yield DDE and DDD. DDE is considerably more stable in the environment, bioaccumulates more than the DDT parent material, and contributes more to the reproductive failure of raptors (Nisbet 1988). Studies of prey species in areas where bald eagles exhibited poor reproduction have shown elevated levels of DDE and related compounds (Wiemeyer et al. 1978, Frenzel and Anthony 1989). Similar studies on other piscivorous raptors have documented elevated levels of DDE in their prey and an associated reduced reproductive performance (Wiemeyer et al. 1975, Koivusaari et al. 1976).

Bald eagles were historically resident on all of the California Channel Islands, but had disappeared by the early 1960s (Kiff 1980, Garcelon 1988). Causes for the decline of eagles on the islands are not well documented, but the decline was concurrent with the manufacture and use of DDT in California during the 1940s and 1950s (Kiff 1980, Garcelon 1988). The use of DDT in the United States as an agricultural pesticide was terminated in 1972.

In 1980 a program was initiated to reintroduce bald eagles onto Santa Catalina Island. Over a 6-year period 33 eagles were reared and released on the island (Garcelon 1988). Early nesting attempts by the eagles failed, and broken eggs were recovered from nests (Garcelon and Roemer 1990). Chemical analysis revealed high levels of DDE in the eggs and in some of the potential prey around the island (Garcelon et al. 1989).

In 1985 a report was made available detailing the past practices of ocean dumping large quantities of environmental contaminants into the Santa Monica Basin in southern California (Chartrand et al. 1985). Between 1947 and 1961 approximately 37- 53 million liters of DDT-containing sludge was deposited into an ocean dump site 16 km northwest of Catalina Island (Chartrand et al. 1985). In addition, it was estimated that from 1954 through 1971 another 1800 metric tons of DDT sludge was discharged through an underwater sewage outfall 3.3 km off the Palos Verdes Peninsula (Chartrand et al. 1985). In 1990 the federal and California State governments filed suit under the Comprehensive Environmental Response, Compensation and Liability Act (42 U.S.C. Section 107) against several companies responsible for discharging organochlorine contaminants into the marine ecosystem.

The goal of this study was to help elucidate the potential pathway of contaminants from the marine ecosystem into the bald eagle population on Santa Catalina Island. This goal was approached by: 1) determining the breadth of prey species fed upon by bald eagles on Santa Catalina Island; 2) examining seasonal variation in prey species taken; and 3) collecting samples of prey species fed upon by the eagles, for later contaminant analysis.

STUDY AREA

Santa Catalina Island is located 34 km south of Long Beach, California. The island is 34 km long, 0.8 to 6.0 km wide, and covers 194 km^2 (Figure 1). Elevations range from sea level to 648 m. There is considerable topographic relief, with numerous steep-sided canyons incising the island. Annual temperatures range from 12 to 20° C near the coast, and yearly precipitation averages 31 cm (NOAA 1985).

The vegetation on Santa Catalina Island has been described by Thorne (1967). Predominant habitat types include: oak woodland, dominated by scrub oak (*Quercus dumosa*) and Catalina cherry (*Prunus lyonii*); grassland, dominated by oats (*Avena spp.*); and coastal sage, dominated by sage (*Salvia apiana* and *S. mellifera*), low shrubs (*Rhus integrifolia* and *R. ovata*) and prickly-pear cactus.

Study Animals

Three active bald eagle nesting territories are found on the island. Because much of the data collected during this study were associated with these territories, a description of their location and attributes of the occupying adults is provided.

- The Seal Rocks territory was located 4.5 km SE of the city of Avalon (Figure 1). It was first used in 1988 and was occupied by an 11-year-old female (ID# K-00) and a 6-year-old male (ID# K-67). The nest was built in a 4 m toyon (*Heteromeles arbutifolia*), on a steep slope approximately 125 m above the water. The foraging area of the pair covered a linear distance of approximately 3.0 km, extending from a point 0.3 km NE of Seal Rocks to Church Rock located at the NW end of the territory.

- The West End territory was located 0.5 km from the NW end of the island (Figure 1). The territory was occupied by a 6-year-old female (ID# WEF) and an 11-year-old male (ID# WEM). A third adult of unknown age (ID# AF) also resided in this territory, and assisted in breeding activities in 1992. The nest was located on a rock ledge approximately 75 m above the water. The foraging area of the pair covered a linear distance of approximately 4.5 km. On the north side of the island the foraging area extends from the western tip of the island approximately 2 km to the SE, and on the south side of the island extends 2.5 km to the SE.

- The Pinnacle Rock territory was located 4.3 km SW of the city of Avalon (Figure 1). It was occupied by a 7-year-old female (ID# K-40) and a 6-year-old male (ID# K-65). The nest was located on a cliff ledge approximately 30 m above the water. The foraging area of the pair covered a linear distance of a 3.5 km extending NW from Pinnacle Rock.

In addition to the eagles residing in nesting territories, three unpaired adult eagles were commonly found in specific areas around the island:

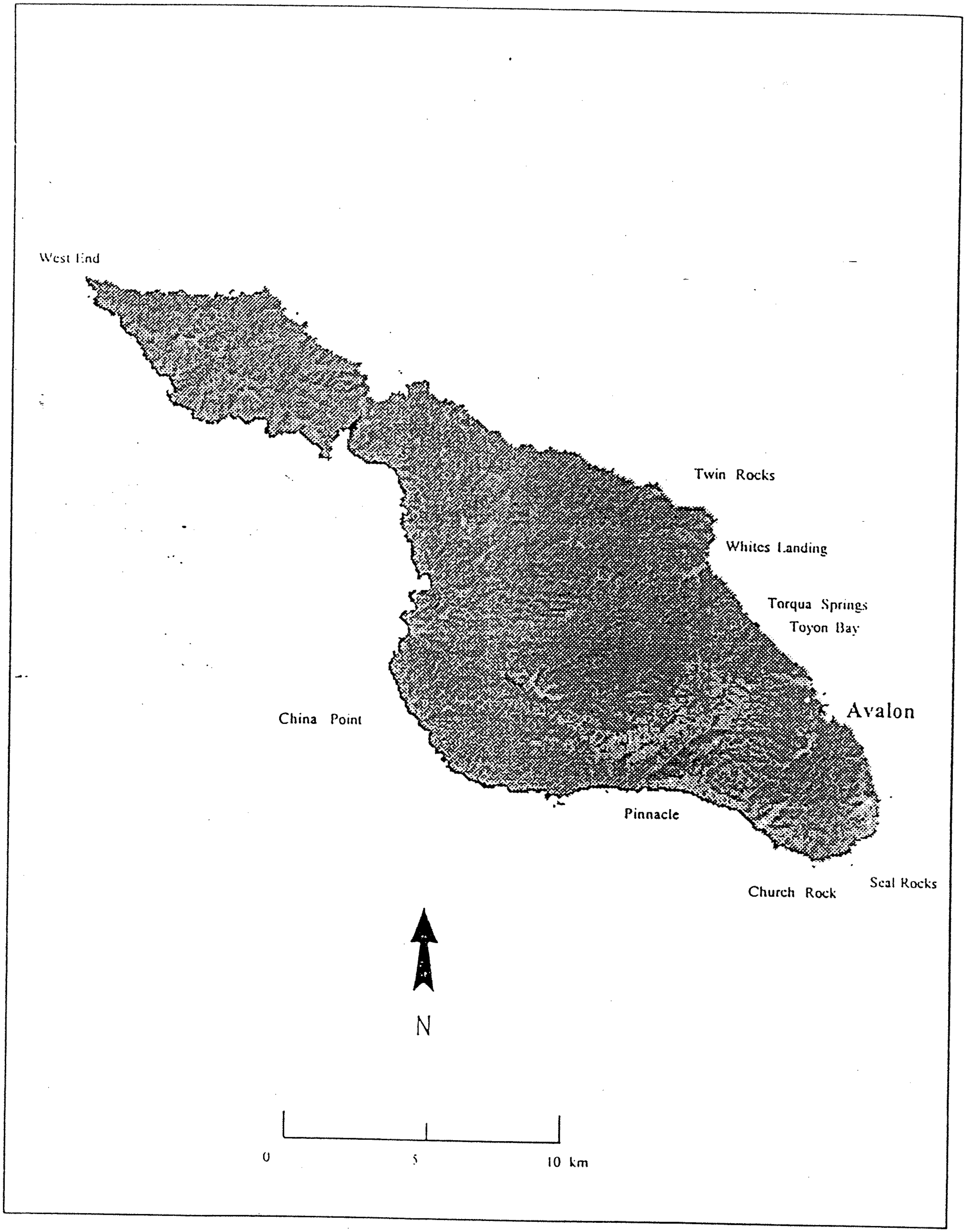


Figure 1. Santa Catalina Island study area showing locations of bald eagle nest territories where contaminant samples and behavioral data were collected.

- A 12-year-old female (ID# CHA) resided in an area referred to as Twin Rocks, located on the NE side of the island approximately 4.8 km NW of the city of Avalon (Figure 1).

- A 8-year-old female (ID# K-22) resided in the area referred to as Torqua Springs, situated between Toyon Bay and White's Landing on the NE side of the island. This area is located approximately 2.5 km NW of the city of Avalon (Figure 1).

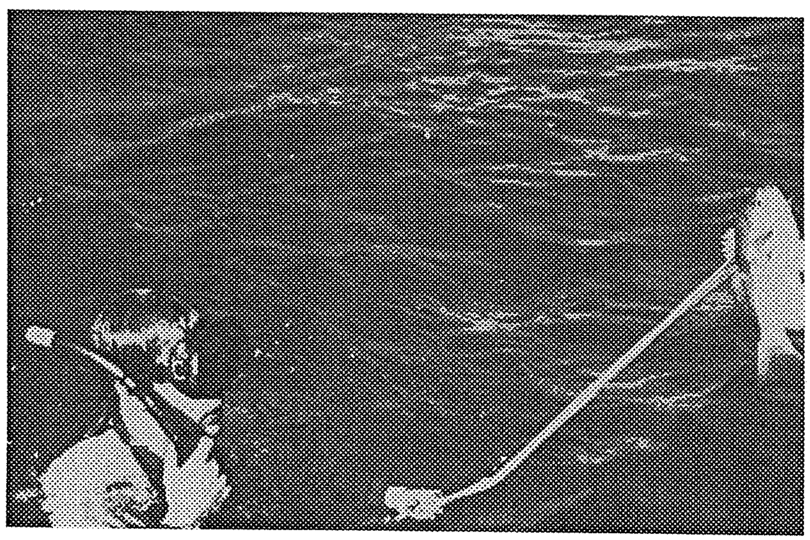
- A 7-year-old female (ID# K-51) resided in the general vicinity of China Point on the SW side of the island. This area is located approximately 7.3 km W of the city of Avalon (Figure 1). This eagle was recovered dead in July of 1992 after being entangled in a fishing lure and line.

In addition to the adult eagles on the island, nestling eagles have been reared and released either by hacking (Garcelon 1988) or by fostering into wild nests on the island. Hacking is a process by which nestlings are raised on artificial nest platforms until they have gained the skills necessary to forage on their own. These birds are equipped with telemetry transmitters which function for approximately 3 years and allow for monitoring of the eagle's locations. Not all of the immature eagles remained on the island, but those that did remain were monitored to determine their foraging activities. One young eagle (ID#K-25) fledged from the nest at Pinnacle Rock in 1992 and was observed in several different locations on the island.

METHODS

Foraging and Prey Delivery Observations

Observations of foraging eagles were conducted from land and water using a 20X spotting scope or 7 X 35 binoculars, and were made between 0600 and 1700 hours. A foraging attempt was defined as an attack on a prey item (capture), feeding upon or recovery of carrion (scavenge), or an act stealing food from antoher species (kleptoparasitism). Foraging attempts included aborted attacks if they were within 1 m of either the water's surface (i.e. fish prey), a visible prey item, or a kleptoparasitism target. Prey items were identified from field observations to the lowest taxonomic level possible.

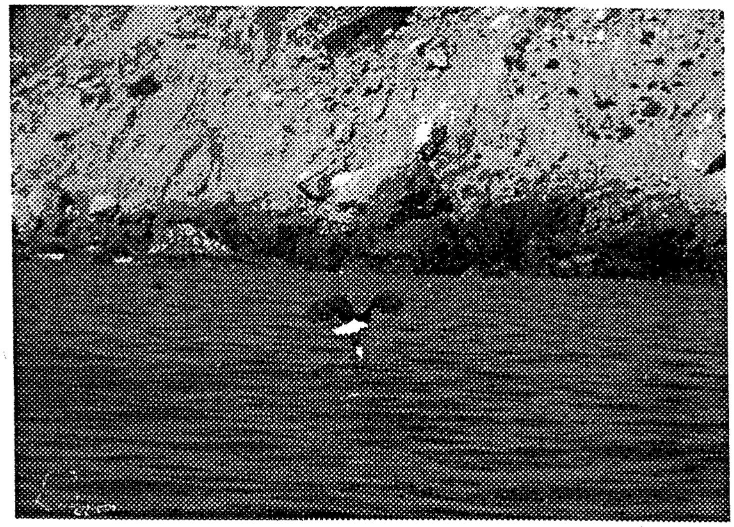


Fish speared for surrogate sample collection.

Prey deliveries to the nest were observed by field personnel at three active nests with 20-45X spotting scopes or by a video monitor. Video cameras were placed at two bald eagle nests on the island as part of a separate study on reproductive activity. Three two-hour observation periods were made each day at each of the three active bald eagle nests. When possible, video recordings were made of prey items in the nest to help verify identification of prey. Foraging and prey delivery observations were recorded on data forms (Appendix A and B).

Collection of Prey Species

When possible, birds observed feeding on large prey were flushed and the prey item was collected for future organochlorine analysis. To avoid harassment, no individual eagle was flushed from prey more than once a month. When eagles were observed feeding on large carrion, tissue samples of the prey were collected after the eagle left the carcass. Breeding birds within view of their nest were not approached for prey item collection during the breeding season.



Eagle flying to shore after catching a fish.

Surrogate samples were collected in order to determine contaminant levels of prey in circumstances where the actual prey item foraged upon by an eagle could not be obtained. Surrogate samples were defined as representative specimens of prey known to be foraged upon by eagles during this study. Surrogate samples were collected as soon and close as possible (within 1 km) to the location where the eagle had foraged on the species. A maximum of 10 individuals per species were collected. For bird species, samples collected were of the same age class (e.g. juvenile or adult) as the prey taken by the eagle. Bird species were collected by shotgun and fish species were collected by hook and line or by spear.

All tissues collected for contaminant analysis were wrapped in aluminum foil, placed in zip-lock bags, and stored in a locked freezer. Bags were labeled with sample number; species identification; as well as method, date, time, and location of collection. Samples of bait, hooks, and line used during surrogate fish collections were stored in zip-lock bags for future chemical evaluation. Bait and equipment used to collect fish could then be tested to ensure contaminant levels found in fish specimens were unrelated to bait that the fish consumed during collection. Organochlorine analyses had not been completed at the time this report was prepared.

Collection of Prey Remains

Prey remains were collected at eagle perch sites and nest sites. The three active bald eagle nests were periodically visited as part of a concurrent productivity study. During these visits, prey remains found in the nests were collected and placed in labeled jars or bags. The number of individuals of any species present in or under the nests was determined by recording the minimum number of individuals of each taxon during each collection (Mollhagen et al. 1972).

After eagles were observed in a successful foraging attempt, they were followed to the feeding perch location. Feeding perches were approached on foot, or by swimming from the boat to the shore after the eagle left the area. A feeding perch commonly used by an unpaired female eagle (K-22) in the Torqua Springs area was also periodically searched for prey remains, even if the eagle was not seen taking prey. Samples of fish, bird, or mammal remains (e.g. scales, bones, feathers) were placed in plastic jars or bags and identified by comparison with reference specimens or by taxonomic experts. Jars and bags containing samples were labeled with the alphanumeric code of the eagle observed feeding on the item, along with the date, time, and location of prey capture.

Data Analysis

Food habits data were collected using four methods: 1) foraging observation, 2) nest observations either by spotting scope or via a video monitor, 3) collection of prey remains at nests, and 4) collection of prey remains at feeding perches. For comparison purposes, data from each method were compiled separately, or with prey remains from both feeding perches and nests combined. When food habits data were collected simultaneously by more than one method, data forms and field notes were carefully reviewed to avoid double counting of prey items prior to data summary.

Prey items were classified into five catagories: fish, bird, mammal, invertebrate, and unknown. Percent diet composition was calculated as the minimum number of prey items in a given taxonomic group, divided by the total minimum number of all prey items taken, multiplied by 100. Data from all collection methods were used to determine the minimum number of individuals of each prey species taken by eagles. Prey items that could not be identified to a taxonomic group were excluded from all diet composition calculations.

Diet composition also was evaluated by month and for individual eagles. Prey remains data were not included in diet composition calculations for these comparisons because prey remains could not be attributed to a specific month or eagle. Percent diet composition also was examined relative to data collection method.

Foraging success was calculated as the number of successful foraging attempts divided by the total number of foraging attempts, multiplied by 100. Foraging success was compared among months and per observation hour. Three types of foraging behaviors (kleptoparasitism, prey capture, scavenging) were compared by calculating the total number of foraging attempts and number of successful foraging attempts for each type of foraging behavior. A chi-square contingency test (alpha = 0.05) was used to test whether foraging success was dependent on type of foraging behavior used (Zar 1984).

RESULTS

Field Effort

A total of 647.5 hours were spent observing bald eagles to obtain food habits data. Observations from land constituted 327.5 hours of this time and observations from the boat made up the remaining 320 hours (Table 1). Observation time included only periods that eagles were in view. An additional 274 hours were spent traveling (by boat or vehicle) to and from eagle foraging areas. A total of 241 hours were spent searching for eagles once researchers were within eagle foraging areas. An additional 1,350 hours of nest observation was conducted using spotting scopes and video monitors during the period nestlings were being reared.

Table 1. Hours of field observation (excluding travel and search time) conducted on bald eagles on Santa Catalina Island, California, from December 1991 through November 1992.

	Observation Time (hrs)		
Month	**Land**	**Boat**	**Total**
December	28.0	6.0	34.0
January	17.0	27.0	44.0
February	20.5	17.5	38.0
March	75.5	2.0	77.5
April	43.5	12.5	56.0
May	10.5	56.0	66.5
June	22.5	20.5	43.0
July	0.0	45.5	45.5
August	4.0	69.5	73.5
September	30.0	48.0	78.0
October	64.0	15.5	79.5
November	12.0	0.0	12.0
Total	327.5	320.0	647.5

Winter storms caused rough seas during fall and winter months, limiting the time researchers could spend observing foraging eagles by boat. In addition, there were mechanical difficulties with the boat motor from December through April, further restricting boat use. Rain during the winter months frequently prevented use of dirt roads, restricting access to observation sites. As a result, equal sampling time over the 12 month period was not achieved.

Foraging Success

A total of 107 foraging attempts were observed of which 71.9 % were successful. Capture was the most common foraging behavior observed (71%), followed by kleptoparasitism (13%), scavenging (11%), and unknown (5%). Of 14 kleptoparasitic foraging attempts, 57% were directed at gulls (*Larus spp.*), 29% at brown pelicans (*Pelecanus occidentalis*), and 14 % at unknown species.

Table 2. Foraging success by month for bald eagles on Santa Catalina Island, California, from December 1991 to November 1992.

Month	Total No. Foraging Attempts	No. Successful Foraging Attempts	Percent Foraging Success (%)	Prey Items Taken Per Observation Hour
December	8	5	62.5	0.15
January	9	5	55.6	0.11
February	4	1	25.0	0.03
March	6	5	83.3	0.06
April	3	3	100.0	0.05
May	14	11	78.6	0.17
June	2	1	50.0	0.02
July	13	6	46.2	0.13
August	19	14	73.7	0.19
September	9	8	88.9	0.10
October	14	12	85.7	0.15
November	6	6	100.0	0.50
TOTAL	**107**	**77**	**72.0**	-------

Foraging success varied among months and with type of foraging behavior (Tables 2 and 3). Monthly foraging success ranged from 0.5 % to 100%, but no annual trend was apparent. Although foraging success was slightly greater for capture compared to kleptoparasitism (Table 3), the difference was not significant ($X^2 = 0.008$, 1 d.f., $p = 0.92$). Scavenging was necessarily successful 100% of the time, and was therefore not included in comparison of success of foraging behaviors.

Collection of Prey and Surrogate Samples

Prey and surrogate samples collected for organochlorine analysis included fish (13 species), birds (five species), and mammals (one species)(Table 4). Five prey items actually foraged upon by eagles were collected. One eagle was flushed from a fish species, Pacific mackerel (*Scomber japonicus*), and samples from

Table 3. Foraging Success of different foraging behaviors used by bald eagles on Santa Catalina Island, California, December 1991 to November 1992.

Foraging Behavior	Total No.	No. Successful	Percent Success
Capture	76	51	67.1
Kleptoparasitism	14	9	64.3
Scavenge	12	12	100.0
Unknown	5	5	100.0

Table 4. Prey items and surrogate samples collected for organochlorine analysis of bald eagle prey on Santa Catalina Island, California, from December 1991 through November 1992.

Prey Species	No. Surrogate Samples Collected	No. Prey Items Collected
FISH		
Black surfperch	1	0
Blacksmith	2	0
California barracuda	1	0
California morey eel	1	0
California sheephead	3	0
Garibaldi	1	0
Halfmoon	20	0
Jackmackerel	2	0
Kelp bass	3	0
Opaleye	15	0
Pacific mackerel	3	1
Senorita	1	0
Topsmelt	4	0
BIRDS		
California gull	1	0
Heerman's gull	2	0
Sooty shearwater	1	0
Western gull	10	0
Western grebe	1	0
MAMMALS		
California sea lion	1	4

four mammal carcasses, all California sea lions (*Zalophus californianus*), were collected after the eagle left the area. The California sea lion carcasses represented two juveniles, two adults, and one of unknown age.

A total of 73 surrogate samples (57 fish, 15 birds, 1 mammal) were collected (Table 4). Collection method varied among and within taxonomic groups. All birds were collected by firearm, and the mammal was sampled by tissue collection. Fish were sampled with hook and line (21 samples), and by spear (35 samples). One fish was recovered already dead. The mammal surrogate sample was from an adult California sea lion.

Of the 10 surrogate western gulls (*Larus occidentalis*) collected, five were juveniles and five were adults. Both Heermann's gulls (*L. heermannii*) were juveniles. Age was not determined for the western grebe (*Aechmophorus occidentalis*), California gull (*L. californicus*), sooty shearwater (*Puffinus griseus*) or any of the 13 surrogate fish species.

Prey Species Composition

For all sampling methods, there were 18 fish species, 13 bird species, three mammal species, and one invertebrate species for which identity could be confirmed (Table 5). In addition to known prey species, two fish and four birds were identified to genus, one fish was identified to family, and one shark (included within the fish taxonomic group) was identified to class (Table 5). There were unidentifiable fish and birds, and also prey items that could not be identified to a taxonomic group.

Two fish species, topsmelt (*Aterinops affinis*) and California grunion (*Leuresthes tenuis*), were indistinguishable in the field and thus were combined during data collection and analysis. Similarly, western grebe and Clark's grebe (*A. clarkii*) differ only slightly in plumage characteristics and were grouped for data analysis.

Nest and Perch Site Prey Remains

Remains of 26 fish (10 species), 27 birds (14 species, 1 genus), and two mammal (2 species) were identified from nests and at feeding perches. Bird remains consisted mostly of feathers, fish remains consisted mostly of scales and fins, and mammal remains consisted of skin and fur.

One bird species and seven fish species were found at feeding perches. Feeding perches at Pinnacle Rock and Seal Rocks each contained the remains of one fish. The feeding perch of eagle #K-22 at Torqua Springs contained remains of one bird and seven fish.

Prey remains found in nests included nine fish species, 13 bird species, one bird genus, and two mammal species. Taxonomic composition of nest remains varied among the three active territories. The Pinnacle Rock nest contained remains of 20 birds, including several whole skins, while the Seal Rocks nest contained remains of five birds and the West End nest had remains of only one bird. Opaleye (*Girella nigricans*) was the only fish identified at all active nests. No other species was found in every nest, but two bird species, arctic loon (*Gavia arctica*) and western gull (*Larus occidentalis*), were found in the Pinnacle Rock and Seal Rocks nests. Pinnacle Rock and Seal Rocks were the only nests with mammal remains.

Table 5. Minimum numbers of prey items and percent diet composition for prey of bald eagles on Santa Catalina Island, California, from December 1991 through November 1992.

Food Item	Individuals N	% of Total	% of Taxon
FISH			
Unknown fish	238	50.4	58.8
Top Smelt (*Atherinops affinis*) or California grunion (*Leuresthes tenuis*)	45	9.5	11.1
Unknown surfperch (various sp.)	33	7.0	8.1
Kelp bass (*Paralabrax clathratus*)	25	5.3	6.2
California barracuda (*Sphyreaena argentea*)	8	1.7	2.0
Blacksmith (*Chromis punctipinnis*)	7	1.5	1.7
Garibaldi (*Hypsypops rubicundus*)	6	1.3	1.5
Halfmoon (*Medialuna californiensis*)	6	1.3	1.5
Unknown mackerel (*Scomber spp., Trachurus spp.)*	6	1.3	1.5
Opaleye (*Girella nigricans*)	5[b]	1.1	1.2
California flyingfish (*Cypelurus californicus*)	4	tr	1.0
Pacific mackerel (*Scomber japonicus*)	4	tr	1.0
California moray eel (*Gymnothorax mordax*)	3	tr	tr
California sheephead (*Semicossyphus pulcher*)	3[b]	tr	tr
Horn shark (*Heterodontus francisci*)	2	tr	tr
Pacific bumper (*Chloroscombrus orqueta*)	2	tr	tr
Spiny dogfish (*Squalus acanthias*)	2[b]	tr	tr
Yellow croaker (*Umbrina roncador*)	2	tr	tr
Calico surfperch (*Amphistichus koelzi*)	1	tr	tr
California halibut (*Paralichthys californicus*)	1	tr	tr
Unknown shark (Class Elasmobranchii)	1	tr	tr
Zebra perch (*Hermosilla azurea*)	1	tr	tr
Fish Subtotal	405	85.8	
BIRDS			
Unknown birds	17	3.6	35.4
Western gull (*Larus occidentalis*)	6	1.3	12.5
Sooty shearwater (*Puffinus griseus*)	4[b]	tr	8.3
Arctic loon (*Gavia arctica)*	3[b]	tr	6.2
Common murre (*Uria aalge*)	3	tr	6.2
Northern fulmar (*Fulmarus glacialis*)	2[b]	tr	4.2
Western/Clark's grebe (*Aechmophorus occidentalis, A. clarkii)*	2	tr	4.2

Table 5. Minimum numbers of prey items and percent diet composition for prey of bald eagles on Santa Catalina Island, California, from December 1991 through November 1992.

Food Item	N	Individuals % of Total	% of Taxon
BIRDS (cont'd)			
Xantus' murrelet (*Synthliboramphus hyoleucus*)	2[b]	tr	4.2
Barn owl (*Tyto alba*)	1[b]	tr	2.1
California gull (*Larus californicus*)	1	tr	2.1
Cassin's auklet (*Ptychoramphus aleuticus*)	1	tr	2.1
Common raven (*Corvus corax*)	1	tr	2.1
European starling (*Sturnus vulgaris*)	1	tr	2.1
Red phalarope (*Phalaropus fulicarius*)	1	tr	2.1
Redhead duck (*Aythya americana*)	1	tr	2.1
Unknown shearwater (*Puffinus griseus* or *P. creatopus*)	1	tr	2.1
Unknown gull (*Larus spp.*)	1	tr	2.1
Birds Subtotal	48	10.2	
MAMMALS			
California Sea lion (*Zalophus californianus*)	5[d]	1.1	62.5
Feral goat (*Capra hircus*)	2	tr	25.0
Harbor seal (*Phoca vitulina*)	1[b]	tr	12.5
Mammals Subtotal	8	1.7	
INVERTEBRATES			
Squid (*Loligo spp.*)	11	2.3	100.0
Total Food Items	472[c]	100.0	

[a]tr=trace amount representing less than 1% of the total.
[b]Species that were described only from nest remains or feeding perch remains.
[c]To prevent double counting of prey remains, total food items may be less than the sum of foraging observations, nest observations, perch remains and nest remains.
[d]The number of California sea lions represents total number of individuals observed being fed upon by bald eagles. The total number of times eagles were observed to feed on these carcasses is 10.

Percent Diet Composition

Based on the minimum number of individuals for all data collection methods, the percent diet composition for eagles was 86% fish, 10% birds, 2% mammals, and 2% invertebrates (Table 5). Most fish and bird prey items could not be identified to species. Thus, unknown fish and unknown birds comprised the greatest percentage of the eagle's diet within their respective taxonomic groups (Table 5). California sea lion was the most common mammal consumed by the eagles.

Percent diet composition also varied among months (Table 6). The greatest percentage of prey species by occurrence were fish for all months except March, when birds were the greatest. Fish were the only taxon of prey that eagles were observed to take during February and August. Invertebrates were observed in the eagle's diet more during winter months (December-March, except February) than other months of the year. Eagles were observed foraging upon birds from March-June and October-November.

Table 6. Percent diet composition by month for bald eagles on Santa Catalina Island, California, from December 1991 to November 1992. These data represent results using observational methods only.

Month	Fish (%)	Bird (%)	Mammal (%)	Invertebrate (%)
December (n=5)	80.0	0.0	0.0	20.0
January (n=5)	80.0	0.0	0.0	20.0
February (n=1)	100.0	0.0	0.0	0.0
March (n=10)	30.0	40.0	10.0	20.0
April (n=27)	70.3	22.3	3.7	3.7
May (n=199)	87.9	9.5	0.5	2.0
June (n=135)	86.7	11.1	0.7	1.5
July (n=36)	97.2	0.0	0.0	2.8
August (n=14)	100.0	0.0	0.0	0.0
September (n=7)	85.7	0.0	14.3	0.0
October (n=12)	58.3	8.3	33.3	0.0
November (n=6)	50.0	16.7	33.3	0.0

Diet also varied among individual eagles, although for all eagles fish comprised the greatest percentage of prey (Table 7). Eagle #K25 was observed to take a greater percentage of mammals, while eagle #K00 took the greatest percentage of invertebrates compared to other eagles. All nine adult eagles were observed foraging on fish, seven foraged on birds, four foraged on mammals, and three foraged on invertebrates.

Sampling Method Comparison

Biases in interpreting food habits data were present in each of the methodologies employed (Table 8). Fish and birds were represented in each sampling method, invertebrates were absent in prey remains data, and mammals were detected by nest remains and foraging observations. Only the prey remains methods were successful in identifying all collected prey items to taxon.

Percent diet composition of eagles varied among sampling methods (Table 9). The foraging observations method detected the greatest percentage of mammals compared to both the nest observations and prey remains methods. Fish comprised the greatest percentage of prey species for foraging and nest observations but were slightly less than the percentage of birds in prey remains data. Prey remains data included almost exclusively fish and birds, with only 3.6% mammal and no invertebrates (Table 9). Thus direct observations of eagles, while foraging and at the nest, were more likely to detect all types of prey that eagles consumed compared to prey remains collection.

Table 7. Percent diet composition for individual eagles (n= total number of prey) Santa Catalina Island, California, from December 1991 through November 1992 These data represent results using observational methods only. Unidentified ea and prey unidentified to taxon were excluded.

Territory [a]	Eagle Identification	Fish (%)	Bird (%)	Mammal (%)	Invertebrate (%)
PR	K40 (n=26)	80.8	15.4	3.8	0.0
PR	K65 (n=51)	96.0	2.0	2.0	0.0
SR	K00 (n=22)	72.7	4.6	9.1	13.6
SR	K67 (n=28)	75.0	10.7	7.1	7.1
SR	K25 [b] (n=6)	0.0	0.0	100.0	0.0
TR	CHA (n=5)	100.0	0.0	0.0	0.0
TS	K22 (n=11)	81.8	18.2	0.0	0.0
WE	AF (n=11)	100.0	0.0	0.0	0.0
WE	WEF (n=16)	93.8	6.3	0.0	0.0
WE	WEM (n=48)	89.6	4.2	0.0	6.3

[a] PR = Pinnacle Rock territory, SR = Seal Rocks territory, TR = Twin Rocks area, T = Torqua Springs area; WE = West End territory.

[b] Fed on one marine mammal carcass on 6 different days.

Table 8. Numbers of prey items, and whether all prey items could be identified to species, for each data collection method used for a bald eagle food habits study on Santa Catalina Island, California, from December 1991 through November 1992.

Method [a]	No. Fish	No. Bird	No. Mammal	No. Invertebrate	All Prey Identified to Species
NR	9	14	2	0	NO
PR	7	1	0	0	YES
FO	11	3	2	1	NO
NO	17	6	0	1	NO

[a] NR = nest remains, PR = perch remains, FO = foraging observations, NO= nest observations.

DISCUSSION

Foraging Success

Foraging success for bald eagles varies according to type of prey being pursued, the age class of the foraging eagle, and the foraging technique employed (Stalmaster and Plettner 1982, Watson et al. 1991). The 71.9% foraging success observed in this study was similar to rates reported by Fischer (1982) of 78%, Harper (1983) of 70%, Haywood and Ohmart (1986) of 78%, and Stalmaster and Plettner (1992) of 73%. Foraging success is likely to be lower when pursuing predominantly avian prey (Bayer 1987, Stalmaster and Plettner 1992).

Table 9. Percent diet composition by observation method for bald eagles on Santa Catalina Island, California, from December 1991 through November 1992.

Sampling Method	Fish (%)	Bird (%)	Mammal (%)	Invertebrate (%)
Foraging Observations (n=77)	74.0	3.9	15.6	6.5
Nest Observations (n=381)	87.1	11.3	0.0	1.6
Prey Remains (n=55)	47.3	49.1	3.6	0.0

Monthly sample sizes of prey obtained by eagles were significantly greater from April through July when chicks were being reared. This was likely due both to the necessity of the adults to obtain food for their chicks and increased observation effort during this period (three additional field personnel). Based on energy requirements calculated by Stalmaster and Gessaman (1982) for captive bald eagles, eagles living on Catalina would only require approximately 400 g of fish/day to meet their energy needs. Therefore, because the energetic needs of the eagles might be met with the capture of only one fish, it is not surprising that relatively few prey items were recorded during the non-breeding period.

The presence of commercial and sport fishing boats appear to be an important seasonal food source for the eagles, as the birds were commonly observed foraging on fish discarded from boats. Observations of eagles feeding on discarded fish have been made in Illinois (Southern 1964) and in Maine (Todd et al. 1982). Eagles would approach small fishing boats to capture discarded fish, or would wait until larger boats had departed and then search the area where the boat had been. During May through July prey deliveries to eagle nests on Catalina averaged 3.4/day and 5.0/day on weekdays and weekends, respectively; fishing boat activity was greatest on the weekends. It is therefore probable that the presence of fishing boats both increased the availability of fish and the foraging success of the eagles. It may also indicate that prey not normally available to the eagles, such as benthic feeding fish, may become available by way of discards from fishing boats.

Interspecific kleptoparasitism is a commonly observed foraging technique for bald eagles (Grubb 1971, Todd et al. 1982, Fischer 1985, Bayer 1987, Watson et al. 1991). The 64% success rate found in this study was similar to the 55% success reported for eagles on the Mississippi River (Fischer 1985, n=65), but greater than the 36% success reported for eagles in Oregon (Watson et al. 1991, n=102). While eagles on Catalina have been observed to kleptoparasitize brown pelicans prior to this study (G. Roemer, pers. comm.), this species has not previously been reported in the literature as a kleptoparasitic target for bald eagles.

Prey Species Composition

Fish

The majority of bald eagle diet studies are based on the collection of prey remains made in nests or around nest trees. While prey remain collections are a relatively accurate indication of prey species consumed during the breeding season, prey remains probably underestimate fish in the diet because fragile boned fish may be completely digested (Imler and Klambach 1955, Dunstan and Harper 1975, Ofelt 1975). Todd et al. (1982) made simultaneous observations at two eagle nests where prey remain collections were made. Observations of fish brought to the nest were 17% greater than nest bowl collections, and 58% greater than numbers derived from remains under the nests. Conversely, diet based on observations of avian species delivered to the nest were 21% less than nest bowl collections and 52% less than collections from under the nest tree. Similarly, Kozie (1986) observed foraging eagles taking 97% fish (n=218), while prey remains collections for nests in the same area (n=19) indicated only 59% fish. It is important to consider these biases when interpreting food habits data for bald eagles.

Birds

Birds are found as a component in the diet of almost all bald eagle food habit studies. Based on prey remains at nests, birds can comprise as much as 45-90% of the prey items in the diet (Murie 1940, Sherrod et al. 1977, Todd et al. 1982, Kozie 1986). Wintering eagles have been found to feed on a large number of birds, most of which were waterfowl (Lish and Lewis 1975, Steenhof 1976, Fielder 1982, Griffen et al. 1982, Frenzel 1984, Stalmaster and Plettner 1992). The percentage of birds in the diet of Catalina's eagles was low compared to most studies, but may have been negatively biased by a reduced field effort during the winter. The highest concentrations of gulls, grebes, murres, and loons in southern California is generally between October and April (Briggs et al. 1987). Boat and weather difficulties reduced field effort from January through March, and may have affected opportunities for observing eagles foraging on birds during that period.

The majority of the occurrences of birds as prey were determined from prey remains. In studies where both observations and prey remains were examined to determine diet composition, birds were always over represented in the diet by prey remains (Todd et al. 1982, Kozie 1986, Watson et al. 1991, Mersmann et al. 1992). This study supported those findings by estimating nearly 5 times as many birds in the diet by prey remains compared to observational methods. This is likely due to birds being taken only occasionally and yet their remains being persistent in the nest.

Although fish represented the greatest proportion of the eagles diet, they may not necessarily supply the most energy. Many of the birds in the eagle's diet had greater body size than the fish, and birds contain a greater percentage of crude fat than fish (Stalmaster and Gessaman 1982). The greater the proportion of fat in the prey species the more potential energy available for the consumer (Stalmaster and Gessaman 1982). Stalmaster and Plettner (1992) found that bird prey supplied 68.5% of the energy for eagles in Nebraska while only making up 3.1% of the prey items in the diet. Therefore, birds may be an important contribution to the energetic requirements of Catalina's eagles, even though fish comprised a greater percentage of the diet.

Because piscivorous birds tend to bioaccumulate contaminants, their consumption may significantly increase the body burden of these compounds in bald eagles (Wiemeyer et al. 1978, Frenzel 1984, Garcelon et al. 1989). Gulls, grebes, murres, and loons; all fish eating birds, were present in the diet of Catalina eagles and may be an important pathway for the acquisition of contaminants. Analysis of three species of gulls collected around Catalina Island had levels of DDE in muscle tissue ranging from 1.5 to 5.6 ppm (wet weight) (Garcelon et al. 1989, Garcelon unpubl. data). Gulls collected from areas where bald eagles exhibited poor reproduction had 2-5 ppm DDE (Wiemeyer et al. 1978, Frenzel 1984, Kozie 1986), meeting or exceeding dietary levels found to cause significant eggshell thinning in captive American kestrels (*Falco sparverius*) (Wiemeyer and Porter 1970, Lincer 1975). Chemical analysis of surrogate samples collected in this study will further elucidate the relationship between DDE and PCB levels in gulls and their contribution to the body burden of contaminants in the eagles.

Mammals

Overall, mammals are the least utilized of the three major vertebrate groups in the diet of bald eagles (Stalmaster 1987), although in some areas comprise a significant portion of their diet (Relfalvi 1970). Because medium-sized mammals, other than the island fox (*Urocyon littoralis*), are absent on Catalina, it is not surprising that mammals made up a small percentage of the diet. Other than feral goats (*Capra hircus*) and pigs (*Sus scrofa*), only marine mammals are present on the island. Large mammals are not generally well represented in nest remains due to the difficulty of bringing carrion from large animals to the nest (McEwan and Hirth 1980).

Other than in this study, marine mammals have not been reported in the diet of bald eagles outside of Alaska. On Amchitka Island, Alaska, Sherrod et al. (1977) reported bald eagles scavenging on carcasses of harbor seals, Steller sea lions (*Eumetopias jerbata*), sea otters (*Enhyrda lutris*), and whales along the shore. Because the marine mammals found in the diet of Catalina eagles feed largely on fish, they have the potential to bioaccumulate contaminants from the environment. Anas (1974) found harbor seals from San Miguel Island to have a mean of 610 ppm (wet weight) for DDT, DDE, DDD, and PCB (combined) in their blubber.

Because organochlorine pesticides have not been been used on Santa Catalina Island (D. Propst, pers. comm.), it is unlikely that the terrestrial mammals on the island contain significant levels of DDE or PCBs in their tissues. Thus, potential sources of organochlorine contaminants for bald eagles on Catalina are restricted to marine prey.

Conclusions

In summary, the composition of fish in the diet can be estimated more accurately by observational methods. Collecting prey remains exclusively to determine food habits of bald eagles may under estimate the importance of fish because they are more completely digested by the birds. Conversely, bird prey will be underestimated by observations sampling methods because they are uncommon prey, and will be overestimated in nest remains because their undigestable parts are more persistent. Small and medium-sized mammals are uncommon on the island and large mammals (other than infants) cannot be brought to the nest. Therefore, while large mammal carrion may be fed upon by the eagles on an opportuntistic basis, they will rarely be found in prey remains and be uncommonly seen by observational methods. Seasonal changes in availability, such as with sea birds, will be reflected in the diet of the eagles but may be more difficult to detect if occurring outside the nesting season.

The data obtained in this study clearly indicate that Santa Catalina Island bald eagles exploit a wide variety of available foods. It is evident that the sport fishing industry influences the diet of the eagles and may provide access to food items not normally available. The findings from this study are in agreement with results from other studies that illustrate the general and opportunistic feeding behavior of these birds.

ACKNOWLEDGEMENTS

The authors would like to thank the Catalina Island Conservancy for access to their land and for use of housing on the island. We are thankful to the Catalina Island Marine Institute, Wrigley Marine Science Center, for providing a boat mooring and helping the project a variety of ways. We would like to acknowledge the assistance of John Schmidt in helping to identify prey remains of birds. Drs. William and Florence MacFarland were gracious hosts at the Marine Science Center and provided helpful insights on fish biology. Dr. Margaret McFall-Gnai provided assistance in the identification of fish scales. Helpful comments on the manuscript were provided by Paula Golightly.

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2 April 1997
Date

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APPENDIX A.

FORAGING OBSERVATION FORM

Date ____________________ **Control Number**_________________ **Bird ID**________

Location ____

Observed from: ☐ **Boat** ☐ **Shore** **Approx. Distance from Bird**____________

Time Start: __________ **Time of Capture:** _________ **Time Stop:** ___________

How Prey was Taken: ☐ **Water** ☐ **Air** ☐ **Terrestrial** ☐ **Carrion**

☐ **Unknown** ☐ **Kleptoparasitized--Species**___________________________

Prey Class (General): ☐ **Fish** ☐ **Bird** ☐ **Mammal** ☐ **Other**

Prey Species (Specific): __________________________ **Age or Size:** _________

UTM of Capture Site: __ __ . __ __ . __ __ __ / __ . __ __ . __ __ __

UTM of Collection Site: __ __ . __ __ __ . __ __ __ / __ . __ __ . __ __ __

Tissue Collected: Yes ☐ **No** ☐ **Type of Tissue Collected:** ___________

Fed Upon by Eagle? Yes ☐ **No** ☐

Comments:____

____

____

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____

____

____

____

Observer: ______________________________

Others Present: ____

PREY DELIVERY FORM

TERRITORY:____________________ OBSERVER: ________________________

DATE	TIME	TAXA	SPECIES	SIZE	TIDE	COMMENTS